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Automated driving – consequences and impacts on transport policy

Report by the Federal Council in response to Leutenegger Oberholzer postulate 14.4169 concerning automated mobility

O353-1246

Abstract

Broad variety of opportunities

Postulate 14.4169, “Automated mobility: driverless vehicles and their impacts on transport policy” requests the Federal Council to submit a report to Parliament on the impacts of driverless cars on transport policy.

Increasing digitalisation will also influence the way we travel in the future. The use of automated vehicles and other opportunities created by the digital world will open up attractive perspectives and have the potential to change Switzerland’s transport landscape in the next 15 to 25 years. These new technologies will greatly contribute towards safer, cleaner and more efficient mobility once automated vehicles have been comprehensively connected and their use can be intelligently combined with the other opportunities that are being rapidly opened up through digitalisation, telecommunications and Internet services.

Attractive new options for road users and public transport services

Automated vehicles will make road traffic safer, improve traffic flow and permit the more efficient utilisation of the available capacities. For road users, journeys in automated vehicles will no longer count as “lost time”, and they will also be relieved from “disagreeable” activities such as parking or driving along congested roads. Driverless vehicles will also enable new user groups such as the elderly, people with disabilities, children, etc. to participate in mobility, and will also increase the attractiveness of car sharing and car pooling.

In the public transport sector, too, in combination with other aspects of the digital world automated vehicles will open up new opportunities for the provision of services that are more efficient, cheaper and more in line with demand. These new options will be especially attractive for covering the first and last miles, as well as for providing services in rural areas. In the longer term, new options such as taxi sharing, car sharing models and other non-scheduled services will expand the present-day range of public transport services, and in some cases replace them. The boundary between public and private transport will become increasingly fuzzy, but at the same time new options and opportunities will open up for combining the various forms of transport. However, this means that operators of local and regional public transport services will have to actively exploit these opportunities and successfully position themselves on the changing market.

Opportunities as well as risks in terms of demand for resources and protection of the environment

The broad variety of new and attractive options will give rise to a general increase in mobility. And the consequences could be more serious if the focus of the new technologies were to be placed on additional comfort and the provision of supplementary options in the area of private transport: the capacity utilisation of individual vehicles could be reduced further due to low occupancy, and thus could intensify the capacity situation on the roads. This would give rise to the need for more space, as well as to reduced energy efficiency, increased energy consumption and thus a higher level of pollution of the environment.

But if the new opportunities opened up by automated vehicles were to be intelligently combined with the other aspects of the digital world, and if the degree of acceptance of the principles of the sharing economy were to be sharply increased, the picture would be quite different: the resulting improvement in traffic flow, together with the use of lighter vehicles and above all the reduction in the traffic volume thanks to the increased use of taxi sharing, would significantly reduce the need for more space and the demand for energy, as well as traffic-related noise and pollutant emissions. Fewer vehicles would be required and the need for an expansion of transport infrastructure would be reduced. There would be less requirement for parking spaces, especially in towns and cities, and the resulting freed-up space could be used for other purposes.

The impacts on the future traffic volume, demand for resources and pollution of the environment will greatly depend on how society, the economy and the public sector make use of these new technologies and the broad-ranging opportunities for developing and providing new services.

Considerable impact on the work environment

Increasing automation will also give rise to changes in the work environment: automated vehicles will reduce, though not entirely do away with, the need for drivers of heavy goods vehicles, buses and taxis. If, as a result of a future comprehensive market penetration of driverless vehicles, car sharing and car pooling were to become widely established, this would mean that fewer vehicles would be required.

Furthermore, due to the elimination of the still existing strong emotional tie to their own car, people would be less willing to pay so much for vehicles in the future. In both cases, the consequences for the automotive industry and their suppliers would be considerable, and these companies would need to redefine their business concepts.

The new technological opportunities and the increasing combination of public and private transport could also have consequences for the operators of local and regional public transport services, who would be forced to rethink their business concepts.

Various central aspects still need to be clarified

It is still largely unclear how the new technological opportunities will be addressed by society and the economy, and at the political level. At the international level, too, there are still various central aspects of automated driving that need to be clarified: for example, the connectivity of vehicles with one another and the infrastructure, the regulations governing the associated exchange of data, the demands to be placed on the necessary digital infrastructure, assuring cyber security and data protection, and dealing with fundamental legal aspects.

The opinions of experts regarding the approach to these central aspects of automated driving still differ enormously, and it is clear that a considerable amount of time will be required before the new technologies will be able to fully establish themselves on the market. As long as this remains the case, it will not be possible to make reliable estimates of the impacts driverless vehicles could have on the traffic volume, the future transport infrastructure, public transport services, the environment and urban and spatial planning. What is foreseeable, however, is the fact that these new technologies are going to be developed and that they have the potential to alter Switzerland’s transport landscape.

CONTENTS

1. Content of postulate / mandate

Postulate 14.4169, "Automated mobility: driverless vehicles and their impacts on transport policy" requests the Federal Council to submit a report to Parliament on the impacts of driverless cars on transport policy, and to answer the following questions:

1. When are automated vehicles expected to be ready for the market or mass production?
2. What impacts will automated vehicles have on the demand for public transport services, and in particular on the services provided by Swiss Federal Railways?
3. How is the demand for road and railway infrastructure likely to evolve once automated vehicles become a means of mass transport?
4. Which regulations and standards will be required or are planned in Switzerland?

In its statement dated 25 February 2015, the Federal Council explained that, while detailed answers to the above questions were not possible at that time, it was nonetheless prepared to make a general assessment of the impacts and outline the potential consequences for transport policy. This is the main purpose of this report, which provides an overview of the ongoing and future developments relating to the automation of vehicles, and thus outlines the associated risks and opportunities for Switzerland's transport system. It also draws attention to the main challenges that go hand in hand with the automation of vehicles and describes how the Federal Council plans to address them.

2. Current situation and content of the report

2.1. Switzerland's high-quality transport system is becoming increasingly stretched

Switzerland possesses a dense motorway network, outstanding public transport services, largely secured financing of its transport infrastructure and a high degree of supply security.

But this high quality transport system is now being stretched to its limits: due to a constantly growing and increasingly mobile population, combined with a high level of prosperity and economic development, Switzerland's transport system is reaching the limits of its capacity. During rush hours, overcrowded trains and buses are a daily occurrence and the number of traffic jams on our roads is increasing every year.

In order to overcome this increasingly severe problem, a further expansion of the transport infrastructure will be unavoidable. In our densely populated country, this infrastructure is rapidly approaching its spatial, ecological, social and systemic limits.

2.2. Urgent need for greater efficiency

In addition to the further expansion of our transport infrastructure, new and intelligent solutions will have to be found so that the functionality of Switzerland's transport system can be assured over the long term. Here the more efficient use of the existing facilities is a key factor.

However, in this regard there are some major shortcomings in the present-day transport system: today, cars stand unused on parking spaces around 96 percent of the time, are expensive to buy and run, and with an average of 1.1 people per vehicle in commuter traffic their capacity is very poorly utilised. Private motorised transport is also subject to malfunctions, and the often emotional behaviour of motorists combined with their daytime travel habits prevent the optimal utilisation of the available capacities.

In the public transport sector, too, the utilisation of capacities during the day is very low (only around 30 percent),[1] and in the area of road as well as rail services the degree of cost coverage is also low (less than 50 percent) [Federal Statistical Office 2016]. By comparison, the degree of cost coverage in the areas of private motorised mobility and heavy goods transport is very high (90 and 97 percent respectively) [Federal Statistical Office 2016].

2.3. Automation and digitalisation in the mobility sector as an opportunity

The use of automated vehicles opens up opportunities to additionally improve road safety and more efficiently utilise the available capacities.

But there is a great deal more potential if this new technology were to be intelligently combined with the rapidly increasing opportunities provided by digitalisation. This includes, for example, the availability of ever larger quantities of data and options for evaluating them, as well as the rapidly increasing dissemination of Internet services. The resulting greater bundling of demand and the provision of more flexible and less expensive mobility services that are more in line with demand have the potential to change and further develop Switzerland's transport system.

But it will only be possible to fully exploit these potentials if people are prepared to significantly change their mobility behaviour. This applies especially to users of cars, who will have to be prepared to share the use of their vehicles with other people and thus surrender a certain portion of their personal autonomy. If it is not possible to provide the necessary attractive services, and if people give preference to personal gains in terms of comfort and the creation of additional options, then driverless vehicles would intensify the existing capacity problems on our roads.

[1] Long-distance traffic

2.4. Content of report

This report is structured as follows:

- Chapter 3 focuses on the existing and future technological developments in the field of automated driving. It describes the interaction between the necessary vehicle technology and the other opportunities presented by the rapid progress of digitalisation, and provides an overview of ongoing developments at the international level.
- Chapter 4 contains an initial assessment of the potential impacts of these developments on Switzerland. It points out that these impacts would vary enormously, depending on the utilisation and market penetration of the new technologies.
- Chapter 5 deals with the associated challenges, the pending issues relating to the social, ethical and political aspects, the creation of the technical prerequisites, as well as planning and conceptual aspects and the various legal requirements.
- Chapter 6 provides an overview of the measures that have already been introduced by the federal government so that it will be able to address the various challenges without delay.
- Chapter 7 summarises the findings and answers the specific questions raised in the postulate to the extent that this is possible based on the current status of knowledge.

3. Context and potentials

3.1. Automated driving has a variety of facets

The essential prerequisite for automated driving is the availability of the necessary vehicle technology that enables the partial or complete adoption of control of the vehicle. If automated vehicles are comprehensively connected with one another, as well as with the road infrastructure, and if they are used intelligently in combination with the other benefits of digitalisation, telecommunications and Internet services, then the potentials would be considerably broader in scope.

By exchanging data with one another and with the road infrastructure, automated vehicles can warn one another about potential hazards, drive more closely behind one another, avoid traffic jams and utilise the available road capacities more efficiently. If these technologies are then intelligently combined with the rapidly increasing potentials associated with the availability of ever greater quantities of data and options for their evaluation, as well as with the broad range of existing and future Internet services, then this gives rise to new opportunities and business models (cf. Figure 1).

Thus an assessment of the impacts of automated driving has to incorporate the three aspects cited above, namely vehicle technology, connectivity and combination with the other potentials associated with the world of digitalisation.

Figure 1: It will only be possible to profit of the full potential of automated driving by combining vehicle technology with comprehensive connectivity and the opportunities associated with digitalisation, telecommunications and Internet services.

3.2. Current and future developments in the field of vehicle technology

Leading car manufacturers and IT companies are currently developing and testing new technologies for automated driving. Google was one of the leading pioneers in this field: it started testing fully-automated vehicles several years ago, and in 2014 presented entirely new and revolutionary concepts in the form of vehicles without a steering wheel and pedals.

By contrast, the automotive industry distinguishes between partially, highly and fully automated (self-driving) vehicles. Partially or highly automated vehicles can assume partial or full control of the vehicle in certain clearly defined situations and subsequently hand it back to the operator, whereas fully-automated vehicles are permanently operated on their own. The resulting degrees of automation of a vehicle can be classified into six categories, ranging from non-automated through to fully-automated (cf. Appendix 1).

Some of these technologies, which are referred to as driving assistance systems, are already being installed as standard features in numerous vehicles, including mechanisms such as adaptive cruise control and lane keeping assist systems. These technologies are constantly being further developed and supplemented with additional functions. Congestion assistant, for example, is a partially automated system that is already available today: it is a combination of adaptive cruise control and lane keeping assist system that automatically assumes control of the vehicle in slow-moving traffic, while the driver merely monitors the system and only intervenes where necessary.

This type of automation of vehicles will undergo further development in the next few years, and a variety of fully-automated vehicles are currently being tested. The following developments in the field of vehicle technology are currently foreseeable:

- **Automated and driverless parking (valet parking)**

  Partially automated systems are already automatically performing certain tasks today, including parking and steering, as well as accelerating and braking. Here the driver only has to monitor the system concerned.

  The so called valet parking is another component of partially automated systems: with this technology, drivers can leave their vehicle when they reach their destination and let it park itself on a given space.

  With a more advanced version, the vehicle can proceed autonomously to any vacant parking space in the vicinity of the specified destination, and can also on its own return from there to pick up its passenger(s).

- **Platooning**

  Vehicles equipped with a common communication standard can be connected with one another to form a virtual team (referred to as a “platoon”). All the vehicles in the platoon follow one another very closely, and are “steered” by the vehicle at the head of the platoon. Platooning is a concept that could be used for both passenger and goods transport by road, but for economic reasons it would be of particular interest for the latter.

- **Automated driving on motorways and main roads**

  A highly automated system assumes complete control of the vehicle on motorways. In the initial development stage, the driver only has to take back control of the vehicle if the system requests this sufficiently in advance.[2] If the driver is unable to respond in time, the vehicle automatically switches into a safe operating mode.

  In the next development stage, the driver no longer has to perform any control functions at all. The system automatically coordinates the safe handover of operation to the driver at the end of the motorway or in critical situations. If this is not possible for some reason, the system takes the vehicle to a safe location where it automatically brings it to a halt.

- **Driverless vehicles**

  At the end of the development chain we find vehicles (cars, buses, goods vehicles) that take over all driving tasks, i.e. drive, park and manage the vehicle’s energy supply. These vehicles no longer need a driver – everyone on board is a passenger. The sole purpose of such vehicles is to safely and reliably transport passengers or goods from A to B. They no longer need a steering wheel and pedals, and are intended for use on complex urban road networks.[3]

3.3. Creation of additional potentials through connectivity

Vehicles already produce large quantities of data today, though used in a proprietary manner and their exchange is generally restricted to the respective manufacturer. And in the opinion of some car manufacturers, this should remain the case in the future.

But this attitude overlooks the fact that the comprehensive connectivity of self-driving (and conventional) vehicles with one another (car-to-car communication "C2C") and with the road infrastructure (car-to-

[2] For example, if the safe operation of the vehicle can no longer be assured due to snowfall or heavy rainfall.

[3] For example, the “Smart Shuttle” pilot project currently being implemented by PostAuto Schweiz AG in Sion (cf. chapter 3.7).

infrastructure "C2I") opens up significant potential for the more efficient use of the available capacities and services:

- By exchanging data of relevance to safety between all vehicles (for example, braking data), it would be possible to substantially increase the level of road safety for all users. It would be possible to minimise the distances between vehicles and thus increase the capacity of the road network.
- Vehicles could be connected to form a virtual and space-saving team (concept of “platooning”, cf. chapter 3.2).
- By communication between vehicles and the road infrastructure it would be possible to utilise the existing roads more efficiently, for example at junctions in urban areas. It would also be possible to automatically inform vehicles about vacant parking spaces, as well as to feed in data from a road network operator regarding recommended deviations, speed limits, etc.
- Thanks to connectivity it would be possible to collect additional and more accurate information about the current traffic situation. It would be possible to estimate travel times more reliably than we can today, as well as for the road network to be more efficiently managed both for private and public transport.

But it is not yet clear how quickly, and to what extent, this connectivity could take place in the future (cf. chapter 5.3).

3.4. Combination with other options thanks to digitalisation

By combining highly-developed vehicle technologies with the options presented by digitalisation, telecommunications and Internet services, it would be possible to significantly improve the existing transport-related services and create entirely new ones. This primarily involves three areas of activity:

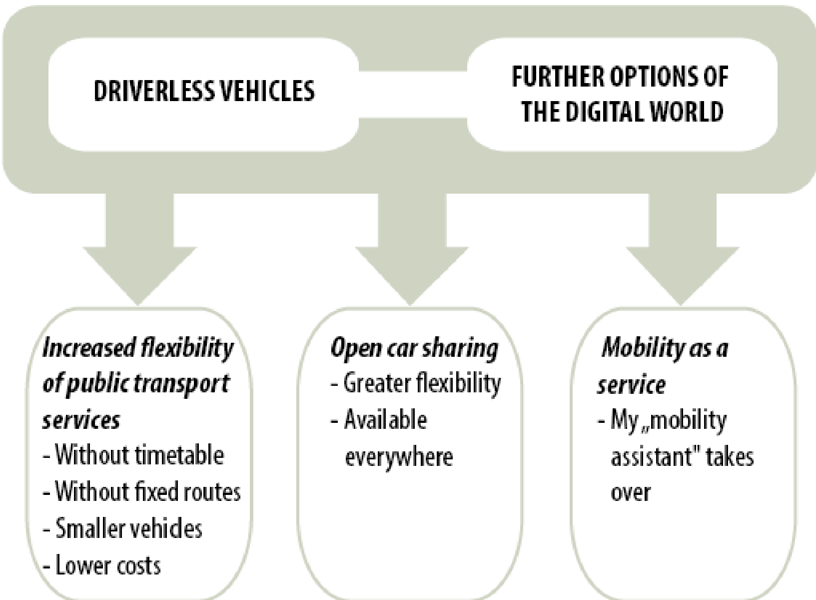

Figure 2: Combining automated vehicles with the options presented by digitalisation would pave the way for the creation of new services and business models.

- **Increased flexibility / customisation of public transport**

  It is conceivable that driverless vehicles could operate within a certain radius without a fixed timetable and without a predefined route network. Here, requests received in real time from users would determine when the journey is to take place and what the route the vehicle is to take. These details would be coordinated, optimised and processed via an overarching computer. Users could request their desired journey via an app, for example, and would receive details regarding the departure time and location via the same medium.

In combination with other aspects of the digital world, self-driving vehicles could enable public transport operators to make their services more flexible and better suited to the needs of their users. Ideally, in the not-too-distant future, public transport users would no longer have to orient themselves on available routes and timetables: instead, these would be based on their own needs.

Already in the short to medium term, these technologies would be of interest when it comes to covering the first and last mile.[4] But in rural areas, too, they could facilitate the provision of services that are both less expensive and more in line with demand – and thus result in better cost coverage for operators.

- **Further development of car sharing and car pooling**

  The further development of already existing car sharing and car pooling services could also go in a similar direction. These services, too, could be made more attractive in the future through the combination of driverless vehicles and the various options associated with digitalisation. By consistently utilising these options it would be possible to efficiently combine the often similar demand patterns, provide different types of vehicles to meet users' specific requirements – for example, vehicles equipped with the desired office installations or attractive entertainment equipment – and enable direct ordering and payment via an app.

  The extent of the (hypothetical) potential for bundling existing mobility requirements in major towns and cities has been demonstrated in the USA with the aid of simulations [Burns 2013], according to which it would be possible to reduce the number of required vehicles by up to 90 percent compared with today if all present-day road travel needs were to be met solely by driverless taxi sharing services. This finding has since been confirmed in studies carried out by the Federal Institute of Technology, Zurich [Bösch 2015] for the greater Zurich area.

  The operation of driverless vehicles would be less expensive than using taxis (for example), and would also relieve users from the need to drive the vehicle themselves. And in the case of already existing car sharing services, they would no longer have to suffer the inconvenience of picking up the vehicle and subsequently returning it to the original pickup point.[5] As before, it would also be possible for customers to use the vehicle together with other passengers or on their own, as desired. Car sharing and car pooling services are also an ideal supplement to public transport, and at the local level they offer a genuine alternative to regional railway services with low utilisation rates.

  As the transportation broker platform already operated by Uber demonstrates, such services are also conceivable without driverless vehicles. But automated vehicles broaden the scope and improve the quality of such services, for example through the provision of the more flexible public transport or car sharing / car pooling services described above.

- **Mobility as a service**

  With this development, users are supported in organising their mobility needs in the broadest sense by one or more central service providers. Users enter their desired destination and arrival time, along with any other preferences they may have, into their "personal mobility assistant". The service provider then proposes the optimal means of getting from door to door, taking account of the user's special wishes, the current traffic situation and the available means of transport. A broad variety of forms of transport may be proposed, and the user chooses the option that he or she finds the most suitable.

  The mobility provider collects all the necessary data that is permitted by law, looks for the best solution for the user, registers the applicable reservation and takes care of the corresponding

[4] cf. the "Smart Shuttle" pilot project currently being implemented by PostAuto Schweiz AG in Sion (chapter 3.7).

[5] In August 2014, a new car sharing service called "Catch a Car" was introduced that is not tied to specific pickup and return points. Following the successful test in Basel, this service was then introduced in Geneva. Meanwhile, the "Mobility" car sharing service is also offering one-way journeys on certain routes.

payment for the various provided services. It is also conceivable that a portion of the necessary vehicle fleet could be owned by a mobility service provider, including driverless vehicles.

3.5. Two scenarios for the introduction of automated driving

The nature of the involved technologies and their potential uses can differ enormously. With regard to the development of automated vehicles, two fundamental approaches are currently under discussion:

- The "**evolutionary scenario**" is based on an assumption of constant development of driving assistance systems culminating in self-driving vehicles. In the short to medium term, vehicles will still be equipped with a steering wheel and pedals, and as before, drivers are able to take back control of the vehicle at any time. People who take pleasure in driving are still able to do so, and they can still maintain emotional ties to their own car.

  In this scenario, which primarily involves the established automotive industry, the main focus is on greater convenience and road safety. Drivers are relieved from "disagreeable" tasks such as looking for parking spaces and driving on heavily frequented motorways, and if they wish they can carry out other activities during their journey. The use of the various options opened up through connectivity and digitalisation is also primarily intended to provide gains in terms of comfort. Although the use of other options such as combining demand in the form of taxi sharing or the provision of customised public transport services is possible, it is not the main focus in this scenario.

  The advantage of this solution lies in the fact that these vehicles can be gradually adapted to the environment and the users, as well as to the operators of the infrastructure and various services.

- The second approach concerns a "**revolutionary scenario"**, which envisages a leap from the present-day situation with conventional vehicles directly to driverless vehicles. Here the focus is on avoiding accidents, assuring the best possible use of the various available forms of transport, and reducing CO_2 emissions. In this scenario the way in which vehicles are used fundamentally changes. Driving pleasure no longer plays a role: what counts here is providing the most comfortable, safe and (ideally) ecological means as possible of travelling from A to B. Vehicles are comprehensively connected and the other options offered by digitalisation are consistently utilised.

  Here, instead of car manufacturers it is technology companies such as Google that are the main players.

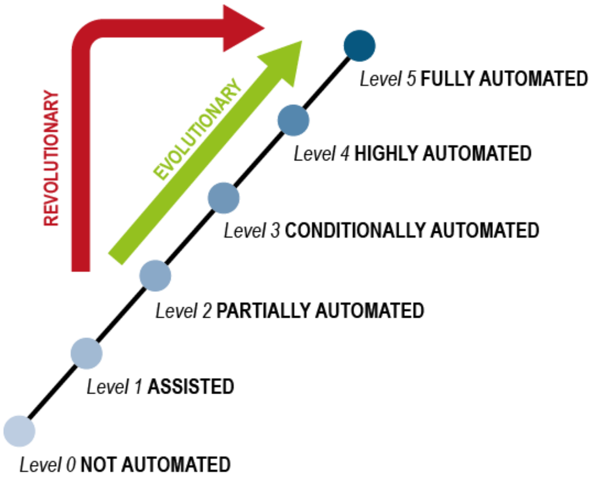

Figure 3: Comparison between the evolutionary and the revolutionary scenario.

It is not yet clear which of these two scenarios is likely to be implemented. The answer will largely depend on how quickly vehicles in level 5 become available and how society wants to utilise the new technological options.

From today's perspective, the most likely development is a location and user specific combination of both scenarios. It is conceivable, for example, that the "revolutionary scenario" could apply for new user groups such as the elderly or people with disabilities in rural areas and for young commuters in urban areas, while "conventional" car users are more likely to orient themselves on the "evolutionary scenario".

3.6. Wide-ranging international developments

The revolutionary move initiated by Google is progressing at an ever faster pace, and other new players in the field of vehicle manufacture are rearing their heads: Uber, for example, which is pushing ahead with its driverless vehicle strategy and introduced such vehicles in Pittsburgh, Pennsylvania on 14 September 2016, or Faraday Future, which presented an experimental vehicle at the beginning of 2016. Tesla has demonstrated that it is not only established manufacturers who can produce vehicles, and is already selling the automation of its cars as a software option.

Based on the criteria of the relevant federal authority [NHTSA 2013], some states in the USA have granted permits for tests with fully-automated vehicles. In this regard, California has issued a relatively restrictive set of regulations. The US Department of Transport is currently holding consultations on a proposal for generally applicable regulations [US DOT 2016].

In 2015 the UK issued a set of guidelines according to which the use of fully-automated vehicles is possible without a licence based on the existing legal provisions [UK DfT 2015].

At the end of 2015, Germany initiated a programme aimed at testing the use of automated vehicles on motorways ("Digitales Testfeld Autobahn") based on the strategy it published earlier that year [BMVI 2015]. Among other things, this strategy calls for the Vienna Convention on Road Traffic[6] (cf. chapter 5.5) to be adapted so that it also permits computers to function as "drivers".

Together with all involved interest groups, the EU published an initial report on connected and cooperative vehicles [C-ITS 2016], which also emphasises the importance of cyber security and data protection. As the next step, the aim is to integrate fully-automated driving into the EU's strategy report.

3.7. Ongoing pilot tests throughout the world

Numerous pilot tests are currently being carried out in the field of fully-automated driving, but drivers still have to be present in vehicles on public roads. For this reason, Google had to retrofit its vehicles in the USA with pedals and a steering wheel. Thanks to its special legislation governing tests with fully-automated vehicles, the UK has issued a set of basic regulations that permit a teleoperator to remotely control a vehicle under certain conditions. With its "Digitales Testfeld Autobahn" programme (see above), Germany wants to pave the way for testing a broad variety of automated vehicles. In Gothenburg (Sweden), Volvo is currently studying the interaction between fully-automated and conventional vehicles on designated public roads. In the Netherlands the focus is on cross-border platooning, while Finland has for some time been developing concepts for mobility as a service. The EU aims to develop its platform for cooperative systems (C-ITS), increase its engagement in automated driving and continue its discussions with all involved players.

The activities listed above refer to some of the most promising developments throughout the world, but in Switzerland, too, there has been plenty of research in this field. The Federal Institute of Technology, Lausanne, conducted a study on driverless minibuses [EPFL 2015]. In 2015, the Federal Department of the Environment, Transport, Energy and Communications (DETEC) granted Swisscom a permit to test fully-automated vehicles on designated stretches of public road for a limited duration [ASTRA 2015], and in June 2016 it issued another temporary permit for PostAuto Schweiz AG to conduct tests with driverless vehicles. The latter is of particular interest in that it involves the transport of passengers by two minibuses without a steering wheel and pedals on a designated stretch of road in the centre of Sion

[6] Implemented in Swiss law (SR 0.741.10)

[PostAuto 2016]. It therefore involves central aspects of the options of “driverless vehicles” and “increased flexibility / customisation of public transport” described in chapters 3.2 and 3.4.

4. Potential impacts of the new technologies

4.1. Identified and as yet unknown impacts

The opinions of experts regarding the potential impacts associated with the use of automated vehicles still differ widely.

What may be regarded as certain is the fact that the use of automated vehicles is going to become a reality and will open up attractive opportunities in the field of road transport. Road travel will become safer and more convenient, access to mobility will be made easier for new user groups, and it will be possible to utilise the available capacities more efficiently thanks to the ability of automated vehicles to travel more closely together and comprehensively communicate with one another. But the extent to which these positive effects actually apply will above all depend on the degree of market penetration of the new technologies and services.

On the other hand, the impacts on central aspects such as traffic volume, space requirements and energy efficiency are still largely unknown. Improvements in these crucial areas would be feasible if the framework of conditions is appropriately defined and the new technologies are used in a targeted manner. But if the focus is placed on gains in terms of comfort and the provision of new options in the area of private transport only, then the use of automated vehicles could give rise to an even greater traffic volume and thus to negative impacts.

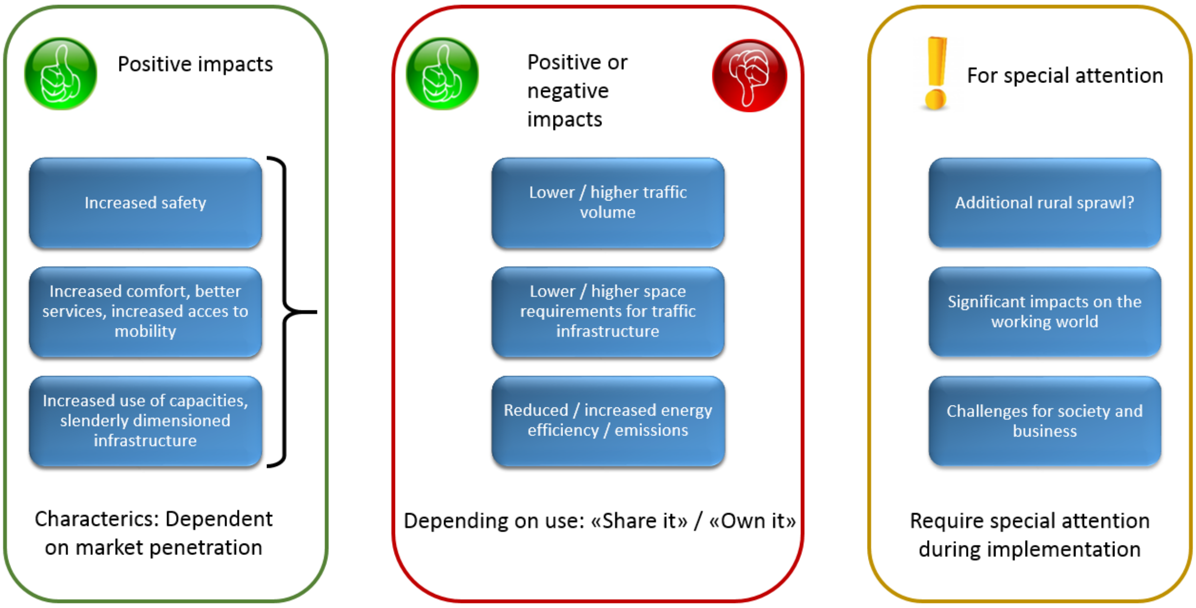

Figure 4: Overview of the potential impacts of the use of automated vehicles and other options opened up through digitalisation.

4.2. Wide-ranging impacts on traffic

Significant enhancement of road safety

According to road traffic experts, around 90 percent of accidents are attributable to human error. With self-driving vehicles, this risk can be eliminated.

On the path towards fully-automated vehicles, new driving assistance systems will help make road travel safer, and safety will be improved even further following the introduction of fully-automated vehicles and their comprehensive connectivity. But even these technologies will not be able to guarantee 100-percent road safety.

Better utilisation of existing capacities

Self-driving vehicles guarantee correct and optimised driving behaviour at all times that is not influenced by emotions. On heavily frequented roads the focus is on the optimal utilisation of the available capacities instead of on personal time saving. With the new technologies it is also possible for vehicles to travel more closely together than they can today. This means that the potential for self-driving vehicles to improve traffic flow on motorways and main roads, and utilise the existing infrastructure more efficiently and effectively in the future, is very high. And it is at its highest when vehicles are comprehensively connected with one another and with the road infrastructure.

The extent of this capacity-increasing effect greatly depends on the degree of market penetration of self-driving vehicles: the higher market penetration, the greater impact is. In the interim period it has to be assumed that the effect will vary considerably according to type and location of the road. It is conceivable, for example, that on motorways and main roads (almost) entirely self-driving vehicles will be used, whereas in towns and cities and on secondary roads there will still be a high proportion of conventional vehicles in use for quite some time.

In the event of a 100-percent market penetration of self-driving vehicles, substantial improvements in the degree of utilisation of the available capacities would be achievable. Here it is conceivable that, on the existing stretches of motorway, it would be possible to provide additional lanes, without having to expand the existing infrastructure, for precisely controlled vehicles that communicate permanently with one another, as well as to allocate these lanes more flexibly than is possible today to the respective traffic flows, depending on the main direction of the traffic. Through the exclusive use of self-driving vehicles it would also be possible to increase the capacities of roads, and especially junctions in urban areas. However, it is by no means certain whether this development will take place in this form. And in any case it would be quite some time before this situation could come into being. Furthermore, self-driving vehicles will have to continue to share the road infrastructure in urban areas over the long term with pedestrians, bicycles, motorcycles and other non-automated vehicles.

Quantified estimates of these impacts still differ enormously and are the focus of ongoing studies. Nonetheless, it may be assumed that the impacts will be significant.

Reduction of road infrastructure dimensioning and installations

Self-driving vehicles optimally adapt themselves to the road. On roads that are used exclusively by self-driving vehicles, this means it is possible to apply reduced dimensioning principles when measuring lane widths or bend radii [Maurer 2015]. This also applies to the dimensioning of parking spaces, which can be designed to save more space thanks to the use of automated vehicles, partly because these require less space for manoeuvring, but also because space is no longer required for people to get in and out of the vehicle.

Savings can also be made in terms of technical installations on roads. In future, it will be possible to largely do away with physical road signs and traffic lights at junctions, etc., because the necessary information will be fed directly into the vehicle. But of course this will only be possible on roads that are no longer used by conventional vehicles and on which reliable communication between the vehicles and infrastructure is assured. And this, too, will require quite some time. The fact also has to be taken into account that pedestrians, cyclists and users of other non-automated vehicles will continue to be on the roads in urban areas in the future.

Uncertainty regarding the impacts on traffic volume and the way in which vehicles are used

The use of automated vehicles and the options associated with digitalisation will enable people to become even more mobile in the future. A self-driven vehicle can be used for carrying out personal activities and will no longer represent “lost time”. If an increasing proportion of the population were to decide not to own a car in the future, mobility would become cheaper than it is today, and the consequence of this would be longer and more frequent journeys. Furthermore, the new options would enable new user groups such as the elderly, people with disabilities, children, etc., to become mobile. The use of self-driving vehicles as “additional living space”, “office premises” or “storage space” could also open up new opportunities. What effect this increased mobility will have on the future traffic volume depends on the way in which self-driving vehicles are used.

The traffic volume could be reduced if self-driving vehicles and the options presented by digitalisation were to be used for comprehensive bundling of different forms of transport and providing more attractive car sharing and car pooling services that are more closely in line with demand. In view of its function, this form of “taxi sharing” corresponds to a public transport service without a fixed route and fixed timetable: these vehicles are used when they are needed and at locations where they can pick up as many passengers as possible. When supplemented with broker plattforms offering attractive multiple transport services (mobility as a service, cf. chapter 3.4.), these options could significantly increase the efficiency of the transport system.

But this would mean people would have to reduce their strong emotional ties to their own car and be prepared to share most of their journeys with others, and thus surrender a portion of their autonomy.

By contrast, if the focus were to remain on personal comfort and possession of an own car, the use of automated vehicles could actually make mobility less efficient than it is today: the average occupancy of a self-driving vehicle could fall to below one person per vehicle if users were to travel to work in it in the morning, send it back home empty in order for it to take their child to school, and subsequently leave it to carry out other activities on their own. In combination with the generally higher degree of mobility, such developments would result in a further increase in the traffic volume. New business models based on the use of automated vehicles for public transport could also place an additional burden on the road infrastructure. On balance, these developments could result in a situation in which the capacity gains accomplished through the use of automated vehicles could be overcompensated and the capacity problems would consequently be intensified.

Opportunities for the public transport sector

The new technologies will also open up attractive opportunities for public transport providers. In particular for services over short to medium distances and in rural areas, new options such as taxi sharing, car sharing models and other services without fixed routes and timetables could supplement, and in some cases substitute, the existing services. This would mean that the boundaries between public and private transport could become fuzzy. The existing services could also change following the introduction of new business models such as mobility as a service (cf. chapter 3.4). New players could emerge as potential recipients of subsidies in the public transport sector and place new demands on the method of subsidisation. Here it is not self-driving vehicles that are behind this development, but the foreseeable trends in the digital realm. These would open up attractive perspectives for the provision of more efficient and cheaper services that are more in line with users' needs. However, this means that operators of local and regional public transport services would have to actively exploit these opportunities and successfully position themselves on the changing market. The same applies to the federal government, the cantons and the municipalities, who as co-proprietors of numerous transport companies would be exposed to this changing environment.

Challenges for rail freight transport

The use of automated vehicles will open up new opportunities for providers of freight services. This would apply to the transport of goods by road, which companies would be able to carry out more cheaply and without restrictions on working hours and rest periods thanks to the use of driverless vehicles.

One of the consequences of this would be that rail freight transport and the federal government's policy of shifting the carriage of goods from road to rail would come under increased pressure.

4.3. Risks and opportunities for the environment and consumption of resources

Energy consumption and emissions

From the point of view of energy consumption and transport-related noise and pollutant emissions, automated driving and the consistent utilisation of the other options presented by digitalisation would open up a variety of new opportunities: vehicles that travel in "platoons" would consume up to 20 percent less fuel [Knight 2013] [Wadud 2016]. Other savings potentials would result from the improved flow of traffic, the widespread use of "eco-driving" by automated vehicles and the increased use of less powerful vehicles [Wadud 2016]. The greatest savings potential would result from the increased use of lighter vehicles and the widespread use of car sharing / car pooling options. Thanks to the lower accident rate resulting from the use of connected automated vehicles, it would be possible for manufacturers to construct lighter models. This would mean that the resources required for vehicle construction could be reduced by around 70 percent versus the present-day level. Also, if sales of vehicles were to fall to around 30 percent of the present-day level thanks to the use of car sharing, then only around 10 percent of the necessary resources for vehicle production would be required compared with the current figure [Folsom 2012] [Riederer 2015].

But the picture would be very different if the road traffic volume were to increase sharply due to the utilisation of the options associated with automated vehicles (more frequent and longer journeys, lower operating costs, new user groups) [Wadud 2016] and if larger vehicles were to be used to an increasing extent ("increased living space").

Demand for space

The use of the new technologies could also open up opportunities in terms of demand for space. If comprehensive use were to be made of the new technologies, this would mean that the existing infrastructure could be used more efficiently than it is today, and the need for its further expansion could therefore be reduced. The same applies with respect to railway infrastructure, which could be used more efficiently than it is today thanks to the more effective distribution of tasks between road and rail services.

Additional space could saved if, thanks to the use of fully-automated parking technologies, parking facilities were to designed to save space and be managed more efficiently than they are today, or if the need for parking spaces could be reduced through the increased use of taxi sharing services in towns and cities.

But demand for space could be higher if the traffic volume were to increase through the use of automated vehicles (despite the potential efficiency gains) and if as a consequence of this the need for an expansion of the existing infrastructure were also to be greater.

4.4. Risks and opportunities for urban and spatial planning

Access to well-connected small to medium-sized towns and major urban centres could be improved as a result of the smoother traffic flow resulting from the use of automated vehicles [Meyer 2016]. And rural regions, too, could become more attractive again as residential areas as a result of improved accessibility and people's readiness to travel greater distances. Both these factors could favour rural sprawl. To avoid this undesirable trend, however, the government has already introduced certain precautionary measures within the scope of the Spatial Planning Act, which contains a variety of provisions relating to the targeted "inward high density construction in residential areas". Periodical monitoring will be required in order to ascertain whether the new provisions will be able to achieve the desired effect and support this spatial planning concept.

The potential reduction in the need for parking space could pave the way for other uses, and the need for drivers to search for parking spaces, which currently accounts for a large proportion of traffic in town centres, would be eliminated [Rodoulis 2014]. In both cases, the attractiveness of towns and cities could be enhanced. In addition, it is conceivable that the requirement of providing parking spaces for new and renovated buildings could be eased, and this would have positive effects on construction costs and demand for space.

4.5. Considerable impact on the work environment

In all sectors of the economy, digitalisation and automation will give rise to changes in the work environment. In the transport sector, automated vehicles will increasingly (though probably never entirely) replace drivers of goods vehicles, buses and taxis, as well as employees of logistics and delivery companies.

On the other hand, new professions will be created for the management and monitoring of automated traffic, as well as in the various necessary supply companies. The use of automated vehicles will also open up opportunities in the "new economy" as well as for the connectivity of vehicles and devices, and in the fields of data management and infotainment [Winterhoff 2015].

If the use of automated vehicles should give rise to comprehensive car sharing / car pooling or the trend towards "access instead of ownership", significantly fewer cars would be required than in the reference case. It is conceivable that the involved companies could evolve into service providers and bring comprehensive mobility products onto the market. This trend has already become apparent: for example, Daimler now owns a car sharing company (Car2GO) together with Europcar, General Motors has invested in a taxi service (Lyft) and various other car manufacturers are now also becoming active in this segment.

This also applies to the operators of local and regional public transport services.

4.6. Conclusions: impacts depend on a variety of factors

The statements presented above indicate to what extent the traffic-related, economic and ecological impacts of the new technological options could vary. Depending on the use of the new technologies, the existing regulatory framework and the degree of social acceptance (cf. chapter 5), various developments are conceivable at this time, ranging from marked improvements thanks to more efficient and safer travel with reduced use of resources on the one hand, and increased road traffic with the associated negative impacts on resources and the environment on the other hand.

The determining factor here will be the extent to which use is made of the various new options such as mobility as a service, increased flexibility of public transport, car sharing and car pooling, etc., so that the chances of a successful automated driving will be increased (cf. Figure 5).

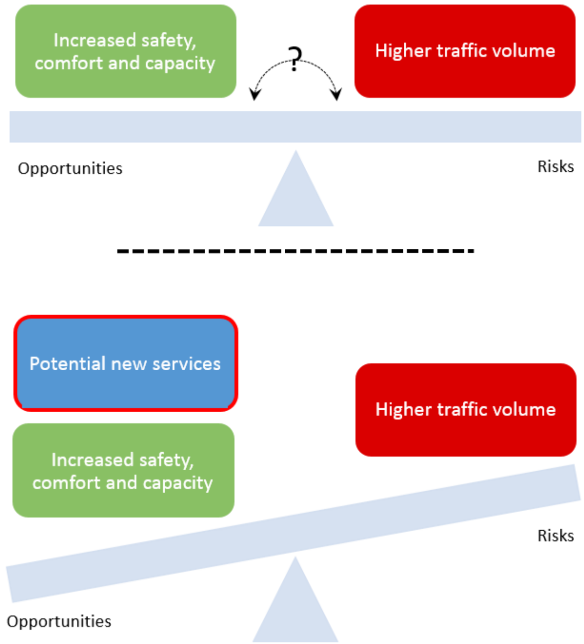

Figure 5: Risks and opportunities associated with the new technological options, with / without utilisation of the additional opportunities offered by digitalisation.

The extent of the potentials arising from the comprehensive and consistent implementation of the new service options can be depicted in a quantitative assessment of the potential impacts in the coming 15 to 20 years according OECD ITF, Fraunhofer and the World Economic Forum (cf. Figure 6).

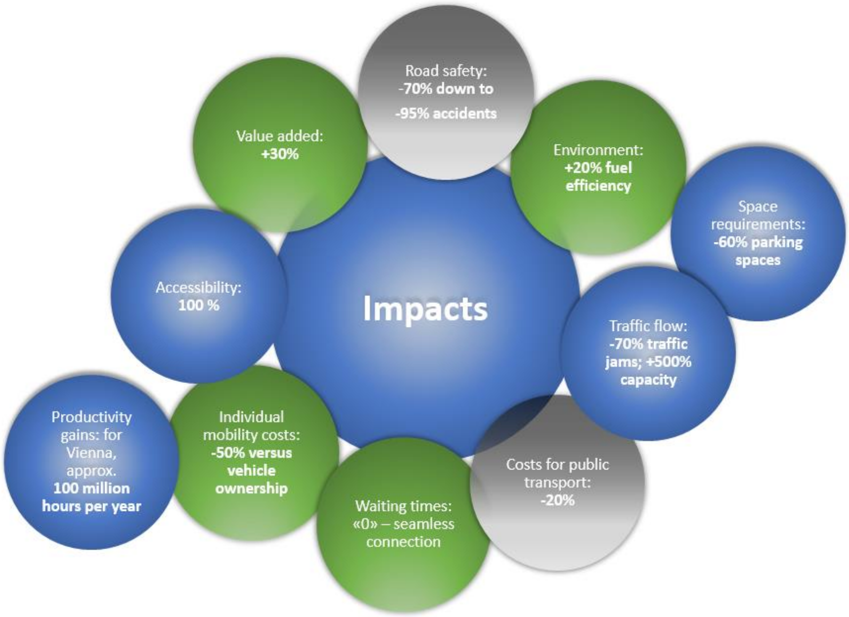

Figure 6: Assessment of the potentials of automated driving and other options associated with digitalisation [AustriaTech 2016 based on World Economic Forum, OECD ITF, Fraunhofer].

5. Challenges and need for action

5.1. Exploitation of potentials as goal

From the point of view of transport, environment and energy policy it is essential for Switzerland to fully exploit the potentials of the new technologies, but the fact has to be borne in mind that this will to a large extent depend on – or even be determined by – developments at the international level.

Nonetheless, the increase in automation will give rise to a variety of challenges both for society and the public sector, and this also applies to the mobility sector. The principal challenges here are:

- To clarify the various social, ethical and political aspects
- To create the necessary technical prerequisites and associated framework conditions
- To successfully deal with the associated planning and conceptual issues
- To adapt the applicable legislation and regulatory framework

5.2. Social, ethical and political aspects

Increasing automation has both a positive and a negative side: on the one hand it undoubtedly opens up attractive perspectives for society and economy, but on the other hand it is also associated with significant risks and profound change processes. And this general assessment also applies to the mobility sector.

Need to define strategic objectives

The impacts of the use of automated vehicles and the rapidly developing options associated with digitalisation will greatly depend on whether, and to what extent, the public authorities define a regulatory framework for the market governing the use of the new technologies.

Within the scope of a political process, society will have to decide which developments would be desirable and which ones would be best avoided. This will require a comprehensive debate on the potential strategic objectives and their associated impacts. The outcome of this process will form the basis for defining the political framework conditions and the role to be allocated to the public sector in selecting the most suitable technological options.

Social acceptance

Defining strategic objectives goes hand in hand with various issues relating to social acceptance.

This initially concerns the readiness on the part of road users to effectively place their lives in the hands of “robots”. It will be necessary to convince users that automated vehicles really are safer [Viereckl 2015], and they will also have to familiarise themselves with the new technologies. The development of the use of automated vehicles will greatly depend on how quickly and extensively this can be accomplished.

But the extent to which automated vehicles will be generally accepted also remains to be seen. For many road users, driving their own car is still associated with strong emotions: owning and driving a car gives rise to feelings of autonomy, independence, privacy and freedom of choice. It also represents an opportunity for self-projection and personal development. For many people, these feelings are so pronounced that their willingness to bear the cost of owning their own car and being able to use it whenever they wish far exceeds rational considerations. The success of automated vehicles will depend on whether a large proportion of the population will be prepared to largely let go of these emotions in the future. This will especially apply for the success of taxi sharing and other alternative forms of mobility.

Data protection, too, is a sensitive issue: automated vehicles and the associated new forms of mobility will generate a huge volume of data, which technically speaking could be used for creating a comprehensive and seamless mobility profile of every user.[7] So the use of these data will also influence the degree of acceptance of the new technologies.

[7] Here it should be noted that smartphone providers are already able to do this today.

Ethical issues

The use of automated vehicles will also give rise to a variety of questions relating to ethics [Doll 2015]: for example, which decision should an automated vehicle take in the event of a collision that can no longer be avoided? Should it always protect the occupants or minimise the overall impacts? Which algorithms should this decision be based on, and who would be responsible for defining them? This also involves questions concerning the value of life and will require a general debate on the topic of machine ethics. These questions are also closely tied to the aspects of liability and vehicle safety (cf. chapter 5.5).

5.3. Creation of the technical prerequisites

A variety of technical hurdles will have to be overcome before it will be possible to bring fully automated vehicles onto the market. Predictions vary considerably as to when and to what extent this will be possible. However, so much progress has been made with the development of the various technologies that the main question now is no longer “whether”, but rather “when” and “how”, they will brought onto the market.

In addition, the creation of the technical prerequisites for the efficient use of automated vehicles and the utilisation of the options presented by digitalisation is of equal importance. The comprehensive exploitation of the potentials of these new technologies will place high demands on the provision and exchange of data, concerning which a variety of controversial issues are currently being debated.

Connections between vehicles and infrastructure

The benefits of connectivity are undisputed. Connectivity is of particular importance for the development of the “learning processes” of automated vehicles. These processes can be greatly accelerated by mutual exchange of vehicle sensor data and the resulting findings that can be used, for example for updating digital maps or optimising the driving behaviour of fully-automated vehicles [Da Lio 2015]. This would give rise to an “autodidactic" Internet of Things (IoT) – described as “Cognitive Internet of Things (CIoT)” [Wu 2014]. Nonetheless, a number of established car manufacturers are of the opinion that vehicles should rely solely on their own sensors. This is a question to be clarified at the international level.

The necessary “intelligence” of the infrastructure is another issue that is still open for discussion. Here it will be necessary to clarify whether, and to what extent, data should be directly transmitted to the vehicle by the infrastructure or, for example, by a service provider. This, too, concerns the question whether vehicles should be equipped with an open interface or, as before, with a closed system. Here, car manufacturers have expressed their concerns about data protection (cyber security), though commercial considerations are probably a significant factor too.

Another question that is involved here is whether, in order to manage traffic flow in the future or influence the choice of route, the operators of the road infrastructure should feed information into vehicles or be able to actively influence the corresponding routing algorithms. In the vehicles in use today, route recommendations are provided by navigation devices which either the vehicle manufacturer or the navigation service provider programs and supplies with data. The operators of road infrastructure do not have access to the data that are generated in this way, nor are they able to influence the resulting recommendations.

Data exchange

The discussions on the topic of connectivity also go hand in hand with questions relating to data exchange and the necessary digital infrastructure. At the international level it will be necessary to decide how it will be possible to ensure that the data can be used and combined as freely as possible, and how the flow of data between users, manufacturers, service providers and authorities can be structured. It will also be necessary to decide which data are to be provided and in which form, as well as what is to happen to the data, who is to have access to them, and so on.

Furthermore, the distribution of tasks between the economy and the public sector regarding the development and operation of the various data exchanges will also have to be regulated. And solutions will have to be found concerning the reliable and efficient flow of the enormous quantities of data that would result from the operation of such a complex common data exchange. The CONVERGE project with its "governance layer" represents a potential model for a jointly operated data exchange [CONVERGE 2015].

Cyber security

The digitalisation of mobility will increase the potential for attacks by hackers. This is already a problem today, for example in the areas of engine tuning and theft prevention. In order to tackle this problem, established manufacturers want to maintain control over the vehicle as an integral system, but with the anticipated increase in connectivity it will become increasingly difficult for them to do so. Studies carried out by the United States Congress [Markey 2015] have meanwhile prompted the industry to agree at last on a minimal declaration of collaboration with the US authorities [Auto Alliance 2015].

It is foreseeable that the extent and intensity of these problems will increase in line with the development of connectivity, and that they could have a direct impact on the functionality of the road transport system. This means that corresponding measures will have to be taken at the national and international levels in order to provide the necessary protection of the population and this critical infrastructure.

Communication

Communication is the basis for data exchange. In view of this, car manufacturers and the telecommunications industry initiated an EU industry dialogue at the 2015 International Motor Show [ACEA 2015]. However, the extent to which this move could contribute towards cooperation remains to be seen. For the time being, the industry is still favouring the application of ITS-G5, the European version of the Wi-Fi standard for vehicles. While this should be adequate for initial tests and findings with data processing, the capacity and technology are unlikely to be sufficient for large-scale use [Shields 2013]. Fourth generation (4G) cellular technologies – LTE and LTE Advanced – would offer solutions, but they still have to be implemented [ERTICO 2015]. The next generation (5G) is currently being developed with the Internet of Things in mind, i.e. focusing on the exchange of small data packages with short latency, which is precisely what is required for communication between vehicles. Switzerland is very well positioned in the field of cellular communications.

5.4. Planning and conceptual aspects

Automation and other technological developments in the mobility sector are going to take place and can be expected to change Switzerland's transport landscape over the long term. However, how and when these changes are likely to take place, and what specific impacts they could have, will remain largely unclear for some time to come. In view of the strong dependence of these developments on the digital world, on the its pace of progress and on the global interconnectivity, it may be assumed that the pace of these changes could be very high in some segments.

By contrast, the progress of the planning and implementation of infrastructure and the development of options for governmental intervention is very slow. Addressing this uncertainty and managing the potentially far-reaching change processes also represent challenges for the public sector at the planning level.

Migration

It has to be assumed that conventional as well as partially and fully automated vehicles will be sharing the road network for quite some time to come. The likelihood is that fully-automated vehicles will become standard in the long term, but in residential areas these vehicles will have to coexist with pedestrians, bicycles and other non-automated forms of transport well into the future. Furthermore, it is likely that people will still want to go on "pleasure trips" in their own car in the future. This coexistence of vehicles equipped with different technologies will be a major challenge for the legislator as well as for the operators and users of roads.

Future need for additional transport infrastructure

As the statements presented in chapters 4.2 and 4.6 indicate, the impacts of automated vehicles on the future traffic volume could vary enormously, and the same can be said for the future need for transport infrastructure.

There are currently no sufficiently reliable findings that would indicate a need to deviate from the already initiated planning of the road and railway infrastructure. From today's perspective it can merely be stated that the road network may be expected to gain in importance as a consequence of the increased use of automated vehicles.

Additional questions have to be raised regarding the future development of the road infrastructure and the structure of the overall network, both of which could change as a consequence of the use of fully-automated vehicles and the connectivity of vehicles and the infrastructure. The introduction of virtual infrastructure, for example the step by step substitution of physical road signs with electronically transmitted ones, is already possible today.

As far as the overall transport situation is concerned, the new requirements can be expected to give rise to various challenges at the interfaces between the different forms of transport. In this context the concept of "mobility hubs" is already under discussion today. The aim here would be to bring together the various transport services and supplement them with additional services such as recreational facilities, shops, etc.

Urban development and spatial planning aspects

Once the use of automated vehicles has been introduced on a large scale and public transport as we know it today has been largely "customised" as described above, it will be necessary to decide how the available road space is to be reapportioned, especially in towns and cities. It will also be necessary to decide which uses are to be allocated to the areas of land that will be freed up thanks to the reduced need for parking spaces and the potential reorganisation of local public transport. Here it will be important to take any new needs into account that could arise in the future, including, for example, facilities for passengers to get into and out of shared taxis, or recharging stations for electric vehicles and the development of mobility hubs.

With regard to spatial planning it will necessary to determine whether the changed circumstances will call for any amendments to the existing legislation.

New operating models in the public transport sector

The potential amalgamation of private motorised and public transport, and the resulting creation of a "customised" form of public transport, can be expected to give rise to new forms of cooperation between the involved municipal, cantonal, and federal authorities, as well as between the public sector, transport service providers and the private sector. These developments will have to be given concrete form and implemented in a carefully planned manner.

New options such as "mobility as a service" (cf. chapter 3.4) will also influence the forms of cooperation in the public transport sector. It will be necessary to regulate the exchange of data between the various providers of mobility services. The options for marketing public transport services and regulating the responsibilities for structuring tariffs will need to be discussed. Here it will be important to take the increasing influence on the part of providers of international platforms into account.

New forms of cooperation

Automation, connectivity and utilisation of other options presented by digitalisation will give rise to new challenges associated with cooperation within the administration: the planning, construction and operation of transport infrastructure will be tied to information and communication technology to an ever increasing extent. The functions of the different means of transport and the services they provide will become increasingly amalgamated. The operation and structure of the various services will become increasingly important within the scope of the planning and implementation of new infrastructure. And even more intensive cooperation between research, industry and the administration will be required for the development, testing and introduction of the rapidly developing technologies.

The increasing understanding of tasks, together with the structures and the hurdles associated with procurement and administration will make it more difficult to deal with these increasingly dynamic change processes. New forms of cooperation will have to be created and facilitated in order to address the foreseeable change processes in the mobility sector.

5.5. Regulatory aspects

Road transport legislation, liability, criminal liability

The homologation and use of driverless vehicles in Switzerland will greatly depend on international agreements and regulations in the area of road traffic. The Vienna Convention on Road Traffic represents the central regulatory framework. Its purpose is to secure and simplify cross-border traffic, and to this end it specifies minimum standards for homologation of vehicles, as well as fundamental traffic regulations. In other words, it sets out to fundamentally standardise road travel throughout Europe. In addition, the regulations of the UNECE (United Nations Economic Commission for Europe) stipulate specific requirements regarding equipment, and components that may be installed in vehicles.

The existing legislation stipulates that the driver must always be in control of his/her vehicle, but this has been placed in question following the introduction of certain driver assistance systems. In view of this, the amendment to the Vienna Convention adopted in March 2016 stipulates that the drivers duty to maintain control of their vehicle is achieved when making use of automated driver assistance systems under the condition that the system concerned can be overridden or deactivated by the driver, or under the condition that other pertinent regulations have been stipulated in international homologation legislation (UNECE regulations). This means that, in principle, vehicles equipped with automated systems can be homologated and used internationally, but as before, a driver is still required and the amended regulation does not release him or her from his/her obligations and responsibility. It appears that the central issue here concerns the prerequisites that need to be met so that drivers can be relieved of their responsibility when using an automated assistance system. In this context, it will be necessary to define the required level of safety of the vehicle, as well as the requirements regarding the corresponding certification.

It will therefore not be possible for driverless vehicles to be used in Switzerland until the necessary level of vehicle safety has been demonstrated and the international legal framework has been adapted. National legislation must not be allowed to lag behind these developments. It will therefore be essential to be able to react flexibly and swiftly to future amendments to the Vienna Convention on Road Traffic and thus perceive the resulting options without delay. In order to achieve the required degree of legislative flexibility, it will be necessary to grant the Federal Council on base of the Road Traffic Law (SVG) the necessary powers to regulate the homologation and use of automated and self-driving vehicles within the scope of the federal ordinances.

Specific regulatory requirements

As a result of the ongoing automation of vehicles through to the development of fully-automated models, it will be necessary for various aspects of the existing national road traffic legislation to be adapted and harmonised with the corresponding amendments at the international level. A brief overview of the most important areas in which changes will be required is presented below.

- **Traffic regulations:** Here it will be necessary to specify the conditions under which drivers could be released from their obligations. For safety reasons, this will not be possible until such time as the status of technology is sufficiently advanced to demonstrably assure a yet to be defined safety level. It will also be necessary to define the criteria relating to the handover and resumption of control between the driver and the vehicle in partially and fully automated models, and other special rules could be introduced, including the specification of shorter distances between vehicles in automated mode. Regulations will also be required concerning how fully automated vehicles can be brought to a halt if necessary, and possibly how they could be controlled remotely.
- **Homologation of vehicles:** The use of driving systems that take over control of the vehicle from the driver raises the question of how this will affect the existing homologation system based on an internationally regulated type approval procedure. In view of the complexity of automated driving systems, it will be very difficult to define the necessary functionalities and corresponding verification procedures in homologation regulations (UNECE regulations). For the homologating authorities and the vehicle testing centres involved in the type approval procedure it will hardly be possible to verify the compliance of vehicles with the required safety level. Until such time as

this becomes possible, the principles of the IT industry will have to be applied, according to which the guarantee of product safety is exclusively the responsibility of the manufacturer.

- **Licensing of drivers:** Drivers will continue to need a licence as long as they are still able to take over control of their vehicle. It is only when fully automated (i.e. driverless) vehicles are in use that a driving licence will no longer be required. In order to offset certain limitations to driving ability, licences could be issued that include the requirement to use driver assistance systems such as emergency brake, night vision or motorway driving assistant. This would enable people who were previously unable or no longer permitted to drive (e.g. elderly persons) to obtain a driving licence or retain their existing one.
- **Criminal liability:** The situation for drivers with respect to criminal liability would be as follows: as long as drivers remain responsible for carrying out driving tasks while using automated driving systems, they cannot be freed from criminal liability for their actions. This would apply, for example, in the case of partially automated vehicles.
  But as soon as a degree of automation is reached in which the occupants are classed as passengers – depending on the system, either in certain situations such as on motorways, or permanently – the requirement of being in control of the vehicle as stipulated in Article 31, paragraph 1 of the Federal Road Traffic Law (SVG) can be repealed or amended – again, either in certain situations or permanently. In these cases, as soon as the driver has handed over control of the vehicle to the system and is no longer responsible for it, he or she can in principle no longer be held liable for the behaviour of the vehicle in traffic. Certain exceptions would still apply here, e.g. faulty operation, manipulation or obvious defectiveness of the system. This means that it would be necessary to subsequently ascertain whether the human or the system was responsible at the time of its occurrence. In order to obtain the necessary evidence it would be necessary to equip such vehicles with suitable recording devices (black boxes).
- **Liability and insurance:** The purpose of compulsory insurance for drivers is to ensure that, in the event of an accident, the damaged party is indemnified through the insurance (i.e. has a direct right to claim). To ensure that this also applies to road travel abroad, multilateral agreements exist between national insurers, and as a rule these are all based on the same liability principles. For example, culpability is not a prerequisite for liability and thus for coverage of damages (causal liability). The reference point for liability is the operational risk of the vehicle. These liability rules thus appear to be appropriate in the case of handover of control to the vehicle. However, increasing automation will have an impact on the internal conditions in that recourse to the manufacturer is to be simplified. And depending on the form of implementation of automated driving, recourse to other involved players such as the provider of navigation services or the operator of the infrastructure could become an increasingly important aspect. A fundamental modification of the currently applicable liability and motor vehicle insurance system therefore does not appear to be necessary. However, insurers are currently discussing potential new solutions [IRGC 2016].

In view of the considerable potential arising from the use of automated vehicles, there is a legitimate interest in facilitating the development of driverless vehicles by creating the necessary legal instruments. On the one hand this involves playing an active role in international bodies that focus on the modification of international legislation and the associated issues in need of clarification. And on the other hand, the trend towards driverless vehicles can also be fostered by adopting a liberal approach to the granting of licences for conducting tests, and by simplifying the associated procedures.

Data protection and accessibility

In order to fully exploit the potentials it will be necessary to connect self-driving vehicles. The associated exchange of data will facilitate the compilation of a comprehensive travel profile for each vehicle, and from the point of view of data protection law, this is problematic.

According to European data protection law and the comparable Swiss regulations, road users have to be informed about which personal data are being collected, and they also have to be able to specify whether and how their data may be used. The information collected from vehicles can easily be processed into personal data, which requires the consent of the persons concerned. To ensure the efficient use of these data it will be necessary to create a legal basis in which in particular the purposes for which the data may be used will have to be defined. Furthermore, it will be necessary to at least define the basic principles according to which data are to be exchanged between fully-automated vehicles. And in order to also include data relating to private stakeholders, it will be necessary to clarify the aspects of data sovereignty and potential access to it. The software used in vehicles will also play an important role: what information does it collect, and what does it pass on? What does it do with the data? In order to create transparency in this regard, calls have been made even for the use of open source, i.e. disclosure of the software used in the vehicle [c't 23/2015].

Other need for action

A variety of other regulatory aspects will have to be clarified, depending on the use and nature of the new technological options, including:

- Regulations for business models such as “mobility as a service”: this could concern issues such as the potential creation of a monopoly, pricing and the comprehensive exchange of data between the various providers. But the relationship with various service providers such as operators of public transport services, providers of car sharing services, etc., may also have to be regulated.
- Restricted access for conventional vehicles: here, for example, it is conceivable that, in the medium term, only vehicles equipped with certain technological installations would be permitted on the motorways.
- Retrofitting of conventional vehicles: In order to maintain a safe and efficient flow of traffic, it is possible that conventional vehicles could be required to be retrofitted with certain technological devices during a transitional period, for example for the exchange of data.
- Various measures in the public transport sector: for example, determining which forms of transport could be used most efficiently in the future in order to secure high quality basic services.

6. Wide-ranging activities of the federal government

With regard to the clarification of central aspects of automated driving, Switzerland is to a very large extent dependent on international developments. It will have to keep a close eye on these and take the necessary measures in good time in order to be able to exploit the associated options. For this purpose, the federal government has already initiated a variety of activities.

6.1. Creation and provision of know-how

- **Research:** Within the framework of road research, the Federal Roads Office (FEDRO) has launched an "automated driving" research package, by means of which the federal government aims to close existing gaps in knowledge and enable research institutions to closely examine this future-oriented topic.

  In the initiating project the extent and modalities for the implementation of this research project are currently being defined. The federal government has initiated another research project at the Federal Institute of Technology, Zurich (ETHZ), aimed at analysing the impacts of self-driving vehicles on the capacities of Switzerland's transport system and the degree of acceptance of potential new types of services.

  The findings from these research projects are being permanently incorporated into the ongoing activities of the federal government in the area of "intelligent mobility".

  The Federal Institute of Metrology (METAS), which possesses a great deal of experience in the areas of data measurement and data security, is currently implementing a project with the aim of acquiring the necessary know-how in the field of "autonomous vehicles and data security".

- **Participation in international bodies:** FEDRO has for many years been represented on the relevant specialised EU committees and is actively involved in the preparation of international guidelines and standards relating to the use of automated vehicles. Switzerland also maintains close contacts at the international level in the area of road traffic legislation.

  These activities ensure that international findings are constantly incorporated into Switzerland's own activities.

- **Exchange and provision of know-how:** Together with industry associations, universities and cantonal organisations, the federal government is actively involved in the Swiss transport telematics platform, its-ch, which is promoting the introduction of transport telematics services and products in Switzerland and networking the various involved players from the areas of science, industry and the public administration. "Intelligent mobility" is one of the main areas of focus in which its-ch organises special events and conferences, and publishes periodical status reports.

  In addition, together with the Mobility Academy of the Touring Club of Switzerland (TCS) FEDRO has initiated the development and operation of a web platform focusing on automated driving. The aim of this platform is to collect national and international know-how relating to the use of automated vehicles and make it available to a broad variety of interest groups.

  By supporting platforms for the exchange of know-how, and by organising special events, the federal government aims to help the relevant stakeholders perceive their tasks, as well as to encourage the process of networking.

6.2. Creation of prerequisites for planning and technology

- **Planning / conceptual prerequisites:** Within the framework of its "Mobility Guidelines", the Federal Department of the Environment, Transport, Energy and Communications (DETEC) is currently defining the basic principles for determining the importance of these new technological options and how they could be utilised at the national level. This will then form the basis for reviewing the federal government's current mobility concepts and infrastructure programmes, as well as its spatial planning concepts, and adapting them as necessary.

- **"Digital Switzerland" strategy and action plan:** A variety of elements of the "Digital Switzerland" strategy and action plan are currently being closely examined under the leadership of the Federal Office of Communications (OFCOM). These include guidelines for interpreting the federal government's data policy, the creation of a national data infrastructure, the development of a comprehensive interdisciplinary and connected traffic management system (including automated driving) with the aid of information and communication technology, and deliberations on cyber security and data protection. All these aspects have a direct correlation with facilitating the use of automated vehicles.

  In addition there are the activities of the industry, which is currently developing and standardising the next generation of communication technology (5G), which could also be of significance for connected and automated vehicles.

- **Technical prerequisites:** The Federal Roads Office (FEDRO) initiated its "Systems Architecture Switzerland" (SA-CH) project a number of years ago, one of the aims of which is to harmonise and standardise the operating and safety equipment on the motorway network. This includes the ongoing and long-term task of transforming the present-day technical installations into equipment that will meet the future requirements. This is a prerequisite for connecting automated vehicles with the road infrastructure in Switzerland.

  Once the technical standards for communication between vehicles and infrastructure have been sufficiently stabilised at the international level, the necessary measures will then have to be defined and implemented within Switzerland.

  At the same time it will be necessary to define and implement the tasks of the public sector relating to the development and operation of comprehensive data networks for the automation of traffic. These could range from the provision of internal data through to active participation in the development and operation of the new digital infrastructure.

6.3. Creation of legal bases

- **Road traffic legislation:** It will necessary to create the legal framework for the use of automated vehicles and exploitation of the options presented by digitalisation in the mobility sector. Initially the goal will be to facilitate the foreseeable short to medium term developments in the field of automated driving in Switzerland, and harmonise them with international activities.

  For this purpose, FEDRO has drawn up a concept regarding the road traffic rules that need to be adapted and issues relating to the homologation of vehicles and licensing drivers. The necessary amendments to the involved legislation are currently being prepared. The aim here is to facilitate the development of technologies up to level 4 of the introduction of automated driving in Switzerland (cf. Appendix 1).

- **Other rules and regulations:** Other requirements such as the need for regulations governing data protection, cyber security, the operation of data networks and the role of the public sector in influencing road traffic, will have to be identified and harmonised with the activities being carried out within the framework of the "Digital Switzerland" strategy and action plan.

  A variety of other regulatory measures will also be required, depending on the attitude adopted by society and at the political level towards the impacts of the various technological developments that will facilitate the use of automation in the mobility sector. These will need to be ascertained, passed on to the relevant authorities, finalised in terms of content and subsequently integrated into the decision-making process.

6.4. Other activities

The federal government is also providing support in the following areas:

- **Facilitating and supporting pilot tests:** The federal government is playing an active role in facilitating pilot tests with automated vehicles. DETEC has already issued initial permits for conducting pilot tests (cf. chapter 3.7), and others will follow.

  Findings obtained from these pilot projects will constantly flow into the ongoing activities of the federal government.

- **Coordination and management of ongoing activities:** Beginning of 2016, FEDRO set up an interdisciplinary core workgroup “Intelligent Mobility” for the purpose of developing concepts for the implementation of intelligent mobility, coordinating the associated activities and implementing the defined programme segments.

  One of these segments is focusing on the development and operation of a data platform, via which FEDRO intends to place the currently existing traffic data at the disposal of interested users.

- **Maintenance of traffic flow on Switzerland’s motorways:** In the past few years, FEDRO has also been taking comprehensive measures aimed at maintaining smooth traffic flow on the country’s motorways. These measures include the constant improvement of traffic bulletins, equipping the motorways with technical installations designed to influence traffic flows, the construction of facilities for permitting the temporary use of hard shoulders by normal traffic, and the planning and implementation of expansion projects within the scope of the programme aimed at eliminating bottlenecks.

- **Finalisation of the mobility pricing concept:** FEDRO and the Federal Office for Transport are currently finalising the mobility pricing concept adopted by the Federal Council. The aim of an ongoing pilot project is to consolidate the various aspects of the concept and gain practical experience in the area of mobility pricing. In the medium to long term, mobility pricing could help offset some of the undesirable developments associated with the use of automated vehicles.

- **Securing of the necessary financing:** At present, mineral oil tax revenue is the main source of road financing. But with the foreseeable trend towards the use of electric vehicles, a new basis will have to be found for this purpose in the not too distant future. Increasing automation could additionally speed up the use of electric vehicles and thus give rise to a greater need for action in this regard. A first step in this direction has been taken in that a levy on electric vehicles was included in the proposed creation of a fund for the financing of motorway and agglomeration traffic. However, this levy is independent on mileage and thus only represents an interim solution. Furthermore, it is still largely unclear whether – and to what extent – the step-by-step automation of road vehicles will result in the need for investments in road infrastructure. The necessary financing will also have to be provided in good time for this purpose.

7. Answers to the questions from the author of the postulate

Based on the currently available knowledge, the Federal Council's answers to the specific questions posed by the author of the postulate as follows:

1. **When are automated vehicles expected to be ready for the market or mass production?**

In the view of the Federal Council, automated vehicles could represent a notable proportion of registered road vehicles within the next 15 to 25 years.

2. **What impacts will automated vehicles have on the demand for public transport services, and in particular on the services provided by Swiss Federal Railways?**

The introduction of automated vehicles will make road travel even safer and more convenient, and it will enable access to (road) transport for new user groups (the elderly, people with disabilities, children, etc.).

The new technologies will also open up attractive opportunities for public transport providers. In particular for services over short to medium distances and in rural areas, new options such as taxi sharing, car sharing models and other services without fixed routes and timetables could supplement, and in some cases substitute, the existing services. This would mean that the boundaries between public and private transport could become less clearly defined. The existing services could also fundamentally change following the introduction of new business models such as mobility as a service (cf. chapter 3.4). New players could emerge as potential recipients of subsidies in the public transport sector and place new demands on the method of subsidisation. Here it is not self-driving vehicles that are behind this development, but the foreseeable trends in the digital realm.

These options will open up attractive perspectives for the provision of more efficient and cheaper services that are more in line with users' needs. However, this means that operators of local and regional public transport services will have to actively exploit these opportunities and successfully position themselves on the changing market. The same applies to the federal government, the cantons and the municipalities, who as co-proprietors of numerous transport companies will be exposed to this changing environment.

3. **How is the demand for road and railway infrastructure likely to develop once robotic vehicles become a means of mass transport?**

The statements above indicate that the automation of road vehicles could have wide-ranging impacts on the future traffic volume, and the same could be said for the future need for transport infrastructure.

There are currently no reliable findings that would indicate a need to deviate from the already initiated planning of the road and railway infrastructure. From today's perspective it can merely be stated that the road network may be expected to gain in importance as the result of the increased use of automated vehicles.

Similarly, it is to be assumed that the use of driverless vehicles will improve traffic flow on the motorways and main roads, and the infrastructure will be used more efficiently and effectively than it is today. This potential is at its greatest if vehicles are comprehensively connected with one another and with the road infrastructure.

The extent of this capacity-increasing effect greatly depends on the degree of market penetration of self-driving vehicles: higher market penetration results in greater impact. But this could vary – at least in the interim phase – depending on the type or location of the road.

In the event of a 100-percent market penetration of self-driving vehicles, substantial improvements in the degree of utilisation of the available capacities would be achievable. Here it is conceivable that, on the existing stretches of motorway, it would be possible to provide additional lanes, without having to expand the existing infrastructure, for precisely controlled vehicles that communicate permanently with one another, and that it would be possible to allocate these lanes more flexibly than is possible today to the respective traffic flows, depending on the main direction of the traffic. Through the exclusive use of self-driving vehicles it would also be possible to significantly increase the capacities of roads, and especially junctions, in urban areas. But whether this development will in fact take place in this form remains to be seen – and in any case, it will be quite some time before it occurs to a significant extent. Furthermore, self-driving vehicles will have to continue to share the road infrastructure in urban areas over the long term with pedestrians, bicycles, motorcycles and other non-automated vehicles.

4. **Which regulations and standards will be required or are planned in Switzerland?**

The homologation and use of driverless vehicles in Switzerland will greatly depend on international agreements and regulations in the area of road traffic. The Vienna Convention on Road Traffic represents the central regulatory framework. It defines the basic principles for traffic regulations, general technical requirements on road vehicles, obligations on the part of drivers and the issue and recognition of driving licences. In addition, the regulations of the UNECE (United Nations Economic Commission for Europe) stipulate specific requirements regarding equipment, and components that may be installed in vehicles.

The existing legislation stipulates that the driver must always be in control of his/her vehicle, but this has been placed in question following the introduction of certain driver assistance systems. In view of this, the amendment to the Vienna Convention adopted in March 2016 stipulates that the drivers duty to maintain control of their vehicle is achieved when making use of automated driver assistance systems under the condition that the system concerned can be overridden or deactivated by the driver, or under the condition that other pertinent regulations have been stipulated in international homologation legislation (UNECE regulations). This means that vehicles equipped with automated systems can be homologated and used internationally, but as before, a driver is still required and the amended regulation does not release him or her from his/her obligations and responsibility. It appears that the central issue here concerns the technical prerequisites that need to be met so that drivers can be relieved of their responsibility when using an automated assistance system. In this context, it will be necessary to define the required level of safety of the vehicle, as well as the requirements regarding the corresponding certification.

It will therefore not be possible for driverless vehicles to be used in Switzerland until the necessary level of vehicle safety has been demonstrated and the international legal framework has been adapted. National legislation must not be allowed to lag behind these developments. It will be essential to be able to react flexibly and swiftly to future amendments to the Vienna Convention on Road Traffic and thus perceive the resulting options without delay. In order to achieve the required degree of legislative flexibility, it will be necessary to grant the Federal Council on base of the Road Traffic Law (SVG) comprehensive powers to regulate the homologation and use of automated and self-driving vehicles within the scope of the Federal ordinances.

Appendix 1: Definition of the six levels of automation

The degree of automation of vehicles is generally classified into six stages [SAE J3016] as follows:

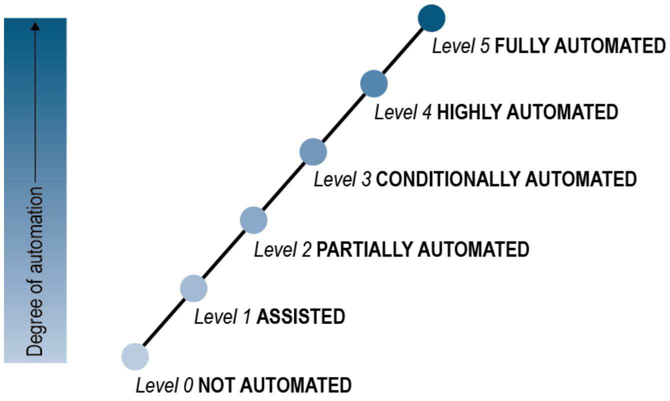

Figure A1: Degrees of automation in accordance with SAE J3016

- **Level 0: Not automated**

  Vehicles are equipped with warning systems only. Drivers maintain complete control of their vehicle.

- **Level 1: Assisted**

  The system assumes either the longitudinal or lateral control of the vehicle, while the driver assumes control of the other axis. Here the driver has to permanently monitor the system and be able to resume full control of the vehicle at any time.

- **Level 2: Partially automated**

  The system assumes both the longitudinal and lateral control of the vehicle on the motorway for a certain period of time or in certain situations. Here the driver has to permanently monitor the system and be able to immediately resume control of the vehicle at any time.

- **Level 3: Conditionally automated**

  As in Level 2, the system assumes the longitudinal and lateral control of the vehicle for a certain period of time or in certain situations. Here the driver is no longer required to permanently monitor the system, but must always be able to resume control of the vehicle in a timely manner if instructed to do so by the system.

- **Level 4: Highly automated**

  Here the system can assume full control of the vehicle in a defined situation, for example on a motorway. The system has to instruct a driver to resume control of the vehicle prior to the termination of the defined situation. If the driver fails to do so, the vehicle has to automatically switch into a minimal risk condition.

- **Level 5: Fully automated**

  Here, no driver is necessary throughout the entire journey. The system assumes complete control of the vehicle, i.e. on all types of road, at all speeds and in all circumstances.

From the points of view of legislation and technology, Levels 3 to 5 are of particular relevance, in that here the driver hands over control of the vehicle to a machine, either under certain conditions or permanently.

Appendix 2: Already existing and foreseeable technologies

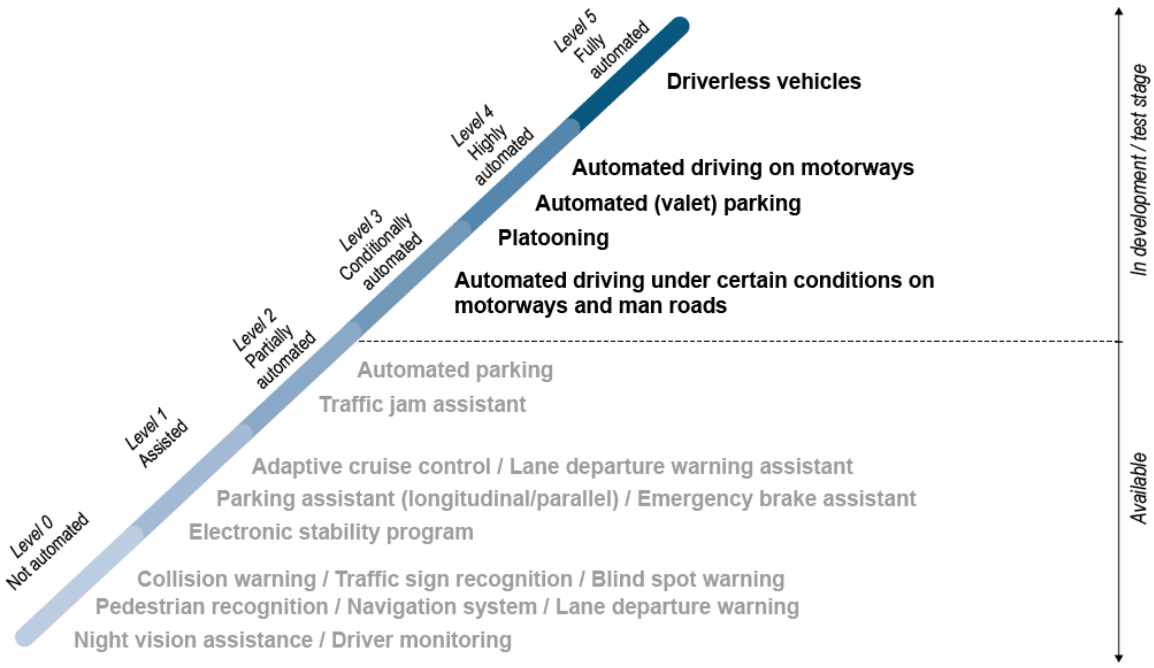

Figure A2: Existing and conceivable developments in the area of automated driving

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